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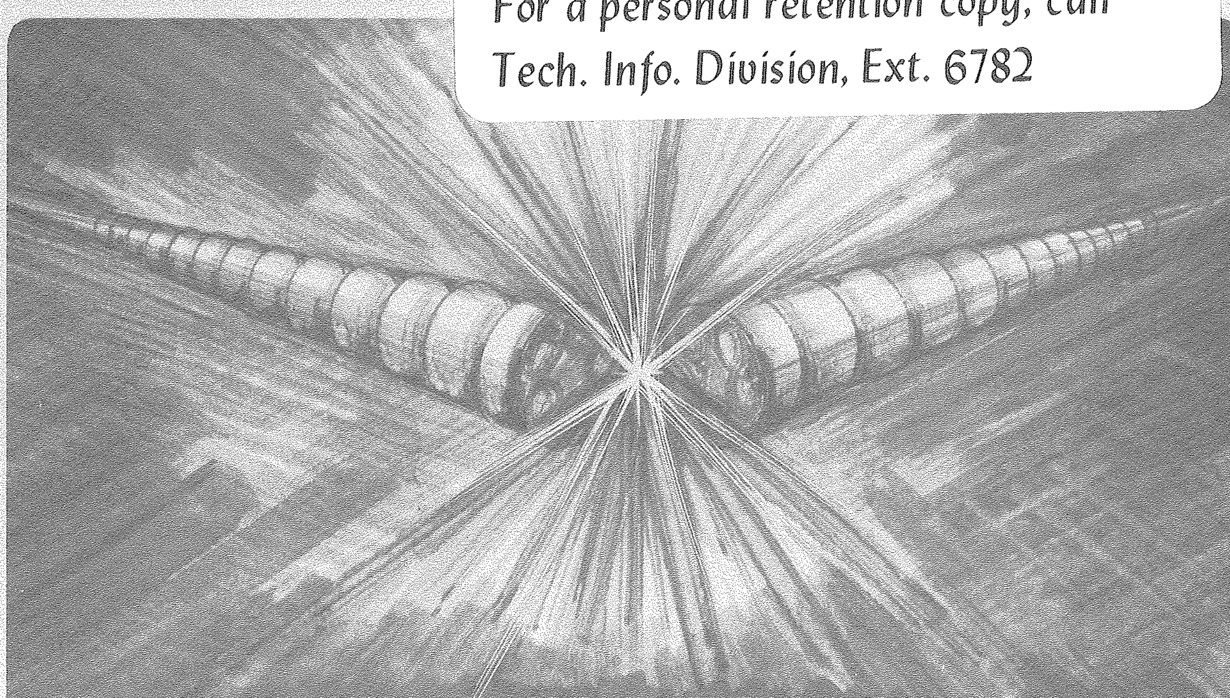

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DISCLAIMER

Electron Suppression in a Multi-cusp Negative Ion Source*

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Abstract

Three different techniques for reducing the background electron density at the exit region of a multi-cusp negative ion source are described.

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The development of negative ion sources for particle accelerators and for heating fusion plasmas has evolved from several milli-amperes to the ampere range. For the production of high energy neutral beams (>150 keV), multi-ampere beams of H^- or D^- will be required. In most negative ion sources such as Ehlers' Penning source,[1] the magnetron,[2] the duo-plasmatron,[3] and the calutron,[4] the extraction of H^- ions is always accompanied by a considerable current of electrons. They are normally separated from the H^- ion beam by applying an $\vec{E} \times \vec{B}$ extraction geometry. These electrons must be intercepted by an electrode[1] and they can contribute a large power drain if this interception potential is high.

In the multi-cusp negative ion source (20 cm diam by 23 cm long) recently developed at LBL,[5] H^- or D^- ions are formed when positive ions from a plasma impact a concave low-work function converter surface which is biased approximately -300 V with respect to the plasma. The negative ions formed are then accelerated across the plasma sheath and pass through the exit aperture which is located between two magnet columns (Fig. 1). The maximum B-field in this region is approximately 100 G which is strong enough to reflect electrons which may have energies as high as 300 eV, but it produces only a small perturbation on the trajectories of the energetic H^- ions.

Although the method described is very effective for containing the energetic electrons within the plasma, Langmuir probe measurements have shown that there is still can be a plasma containing very low energy electrons at the source exit (Fig. 2). The B-field in the exit region cannot confine low energy positive ions (H^+, H_2^+, H_3^+) from the plasma efficiently. Electrons found in this region can either diffuse across the magnetic field with the positive ions, or they can be produced by photons illuminating surfaces near the exit region. In this letter, we demonstrate that the plasma density (hence the electron density) at the source exit can be reduced substantially by three different techniques.

To suppress the electrons at the source exit in this multi-cusp negative ion source, one method is to generate a negative plasma potential (for positive ion containment) by injecting a large quantity of low energy primary electrons into the source plasma.[5] The energy of these electrons must be sufficiently low as to cause no additional ionization. The Langmuir probe characteristics in Fig. 2 indicate that when the plasma potential at the center of the source falls below the potential of the chamber wall (anode), the ion and electron densities at the source exit are both reduced by approximately two orders of magnitude. In this technique, the injected low-energy primary current is typically twice the discharge current. For high density operation, a large number of filaments are required to provide the necessary cathode area for space-charge limited emission at the reduced voltage.

An alternative scheme to prevent positive ions from reaching the source exit region is to install a positively biased electrode in between the two magnet columns as shown in Fig. 1. This electrode which also defines the size of the exit aperture is connected by a dc power supply to the chamber wall. If no bias voltage is applied (V = 0), the electrode which is at anode potential draws mainly ion current (Fig. 3). The electron densities at three different positions from the source center are shown in Fig. 4. The ion current drawn by the electrode saturates at V = -2 V. Thus when the electrode is more negatively biased, there is no significant change in the Langmuir probe characteristics. However, if the electrode is biased positively with respect to the anode, the electron density at the exit region starts to decrease. In fact the electrons at the exit region (R = 10 cm) can be reduced to a negligible amount with V ≈ +5 V (Fig. 4a). As one moves 3 cm into the source (R = 7 cm), the bias on the electrode produces very little perturbation on the local electron density (Fig. 4c). The positive bias voltage on the electrode reflects most of the positive ions coming from the source plasma toward the exit region and consequently reduces the number of electrons that they carry along or attract. In addition the electrode sweeps away the electrons that are trapped in the magnetic field lines. This may be the reason why the plasma potential becomes positive when the bias voltage is increased from zero to +5 V (Fig. 4b).

In this source, the filaments are normally operated in the emission-limited regime with the discharge voltage V_d adjusted to 70 V. The potential of the source plasma rides approximately 3 V above the anode potential. If the discharge voltage V_d is gradually reduced to about 42 V, it is found that the plasma potential in the source falls below that of the anode (Fig. 5b). At the same time the positive ion and electron densities at the exit region are greatly suppressed as shown in Fig. 5a. When the source is operated with a discharge voltage $V_d \simeq 40$ V, a primary electron has enough energy to make about one ionization reaction. However, the degraded primary can be confined very efficiently in the source (the loss rate of a primary electron in a multi-cusp system is proportional to its energy[6]). The presence of a large number of these degraded primaries will produce a negative plasma potential and the effect will be the same as the first method described. A decrease in V_d is always accompanied by an increase in the discharge current I_d in order to maintain the same converter current.

In conclucion, three different techniques, each of which provides a potential to prevent plasma ions from reaching the exit region can suppress the electrons at the exit area of a multi-cusp negative ion source without producing any perturbation to the source plasma. In fact, when the source is operated in the presence of cesium, these techniques will reduce the loss of Cs^+ ions through the exit aperture.[7] If an exit aperture defining electrode is present, the second scheme could be applied very conveniently.

We would like to acknowledge the technical assistance by M. D. Williams.

References

1. K. W. Ehlers, Nucl. Instrum. Methods 32, 309 (1965).
2. Yu I. Bel'chenko, G. I. Dimov, and V. G. Dudnikov, Nucl. Fus. 14, 113 (1974).
3. K. Prelec an Th. Sluyters, Proceedings of the Second Symposium on Sources and Formation of Ion Beams, Berkeley (1974).
4. J. E. Osher, F. J. Gordon, G. W. Hamilton, Proceedings of the Second International Conference on Ion Sources, Vienna, (1972) p.876.
5. K. W. Ehlers and K. N. Leung, Lawrence Berkeley Lab. Report, LBL - 10013.
6. K. N. Leung et al., Rev. Sci. Instrum. 49, 321 (1978).
7. Yu. I. Bel'chenko, G. I. Dimov, and V. G. Dudnikov, Proceedings of the Symposium on Production and Neutralization of Negative Hydrogen Ions and Beams (Brookhaven Nat. Lab., Sept. 1977).

Figure Captions

Fig.1 Schematic diagram of the multicusp negative ion source.

Fig.2 Langmuir probe traces obtained at (a) the center and, (b) the exit of the source with and without low-energy electron injection.

Fig.3 Current drawn by the electrode at the ource exit as a function of the bias voltage.

Fig.4 Langmuir probe traces obtained at three different positions for several bias voltage on the electrode.

Fig.5 Langmuir probe traces obtained at the source exit for different discharge voltages.

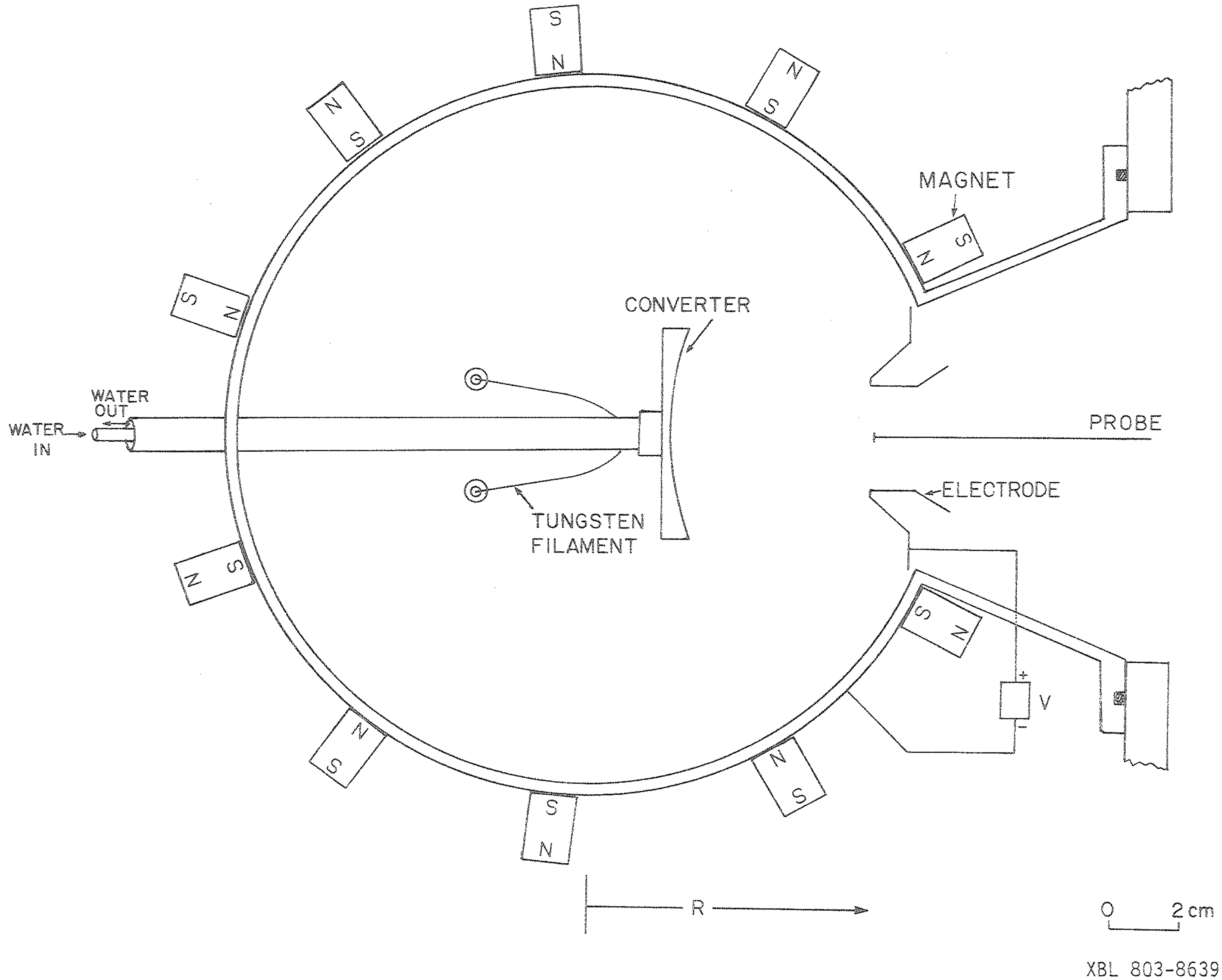
S
N
MAGNET
CONVERTER
WATER OUT
WATER IN
PROBE
ELECTRODE
TUNGSTEN FILAMENT
V
R
0 2 cm
XBL 803-8639

Fig. 1

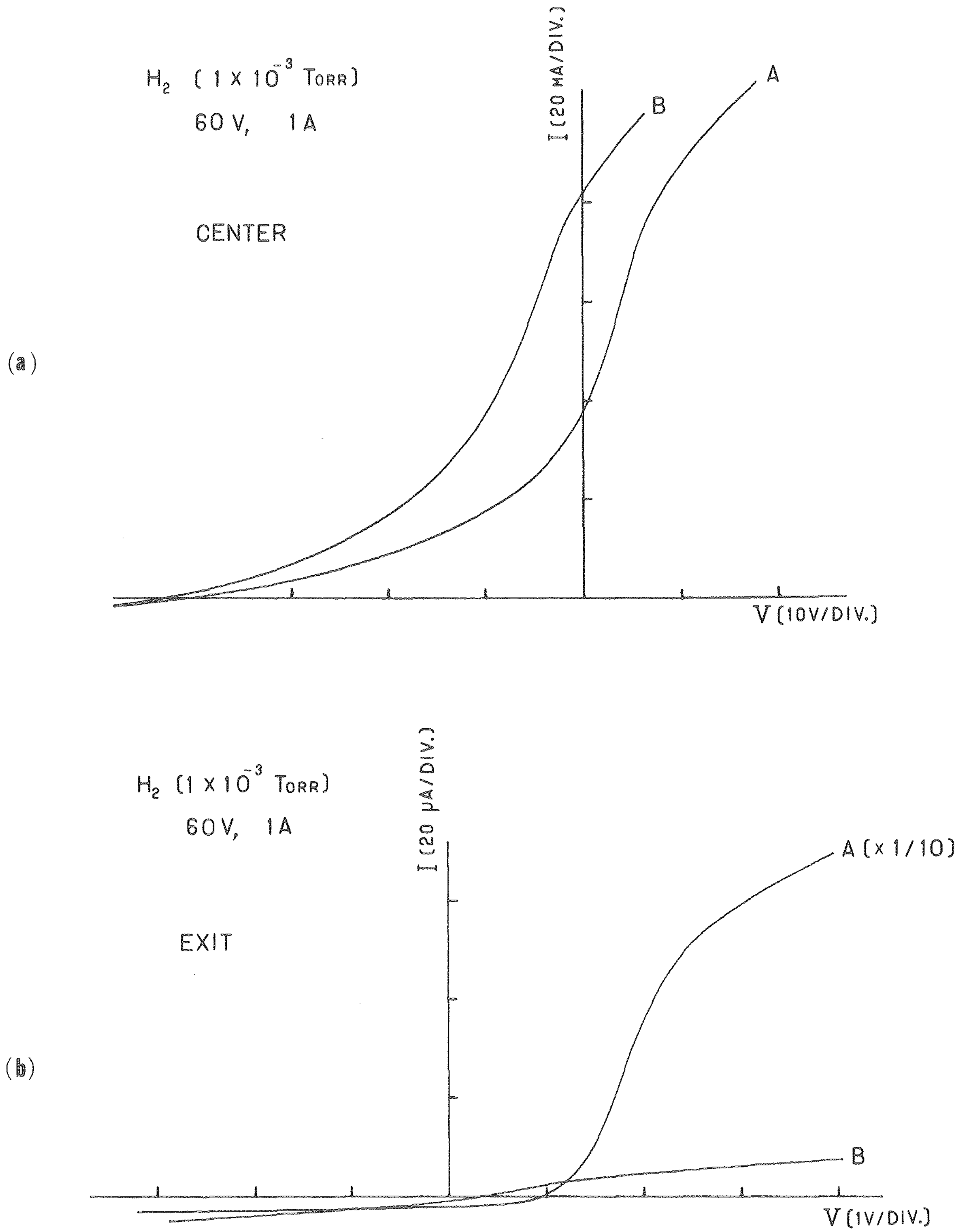

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Fig. 2

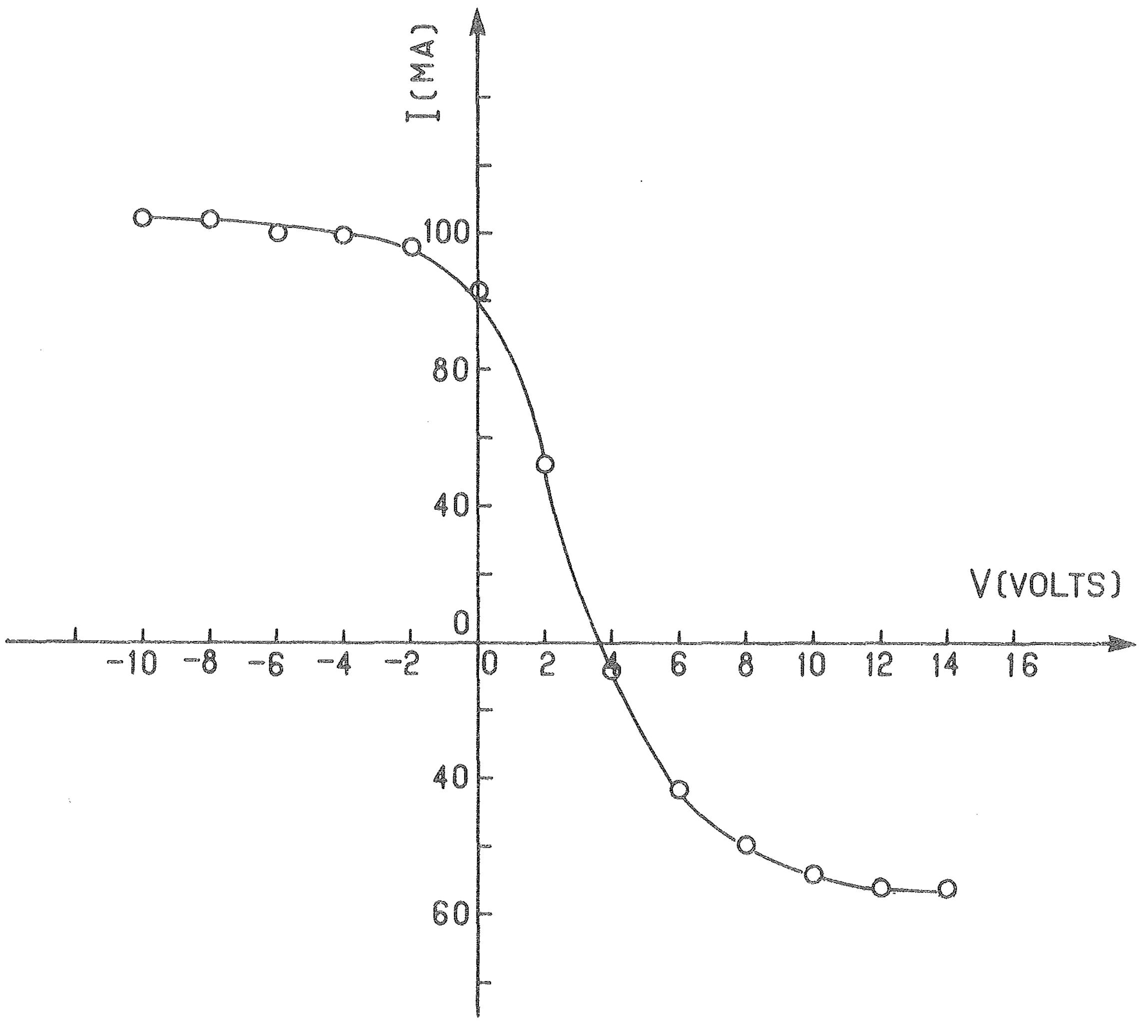

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Fig. 3

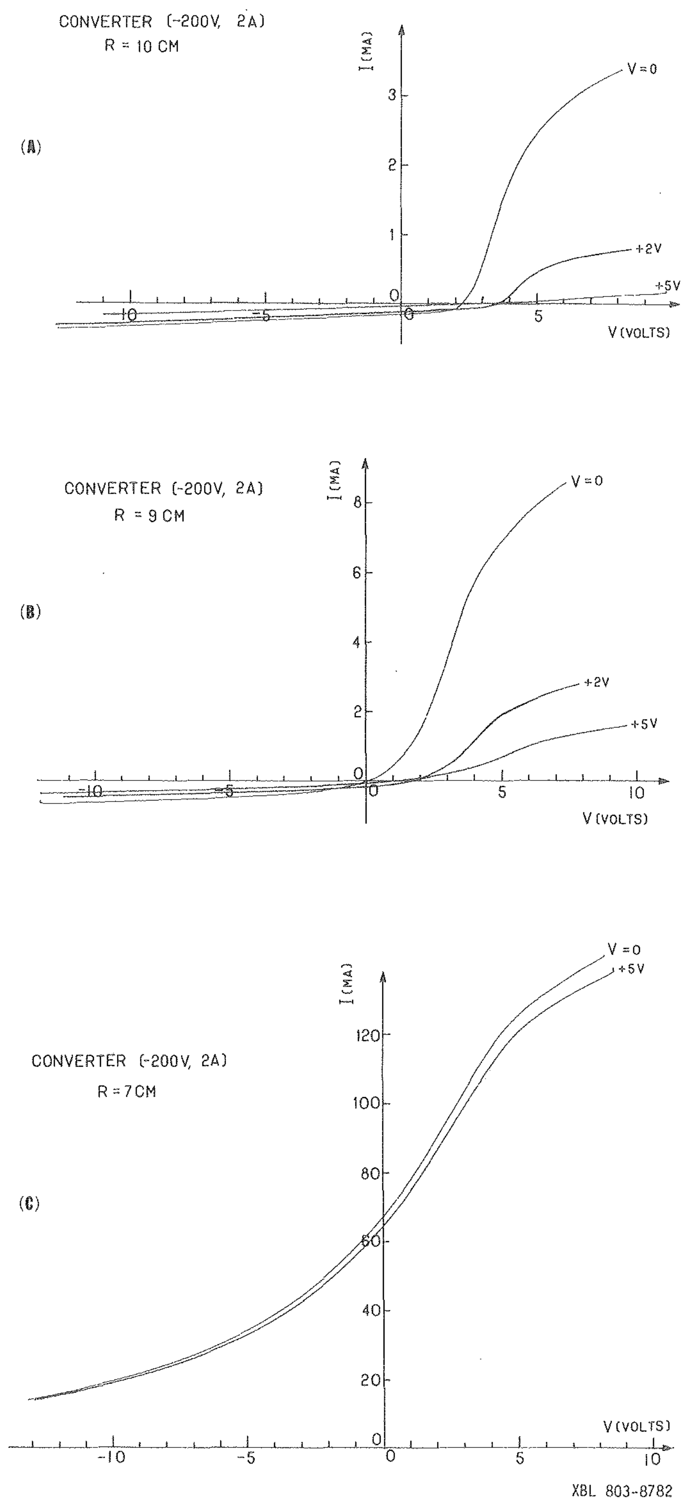
CONVERTER (-200V, 2A)
R = 10 CM
(A)
I (MA)
V=0
+2V
+5V
V (VOLTS)
CONVERTER (-200V, 2A)
R = 9 CM
(B)
I (MA)
V=0
+2V
+5V
V (VOLTS)
CONVERTER (-200V, 2A)
R = 7 CM
(C)
I (MA)
V=0
+5V
V (VOLTS)
XBL 803-8782

Fig. 4

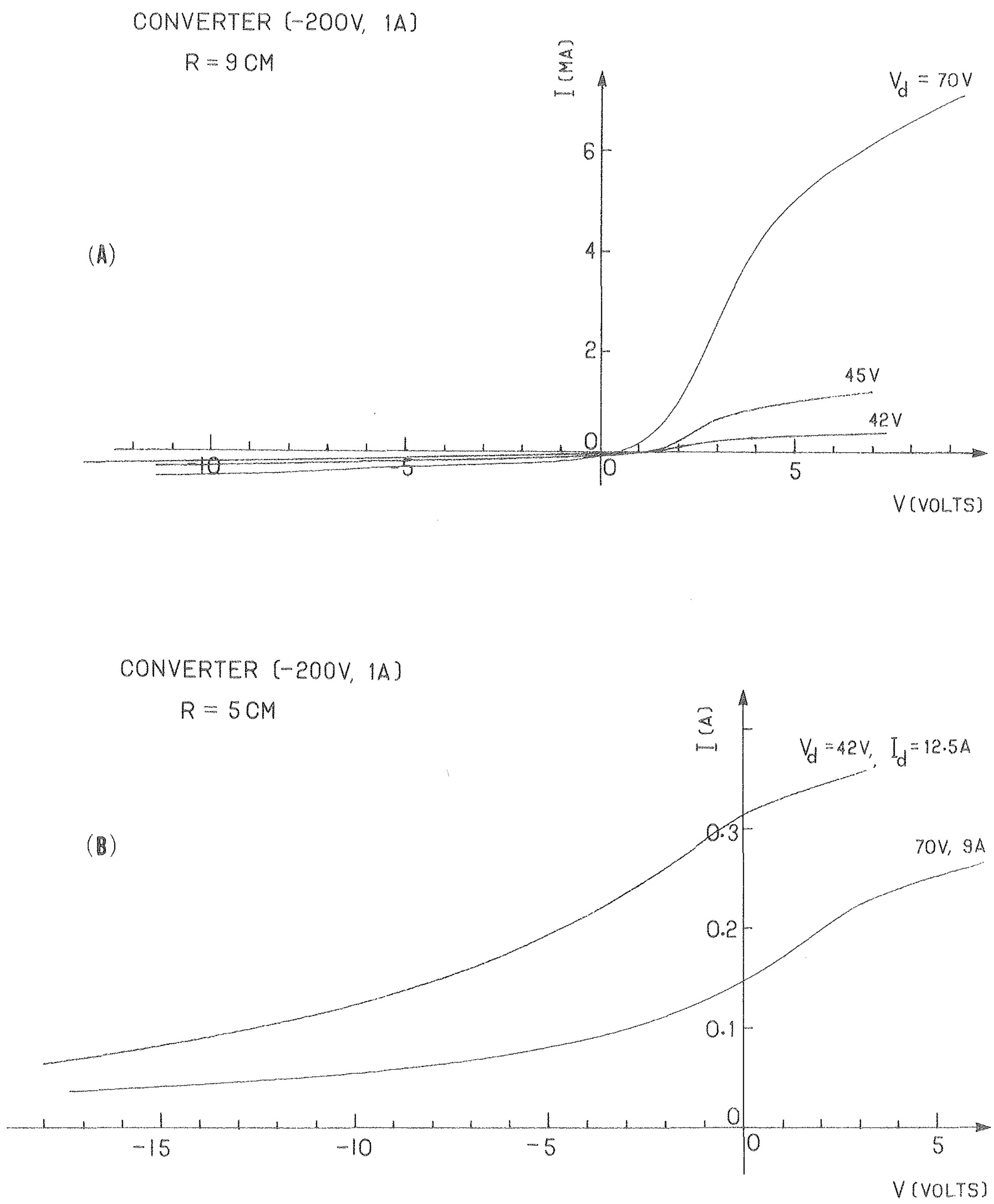

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Fig. 5